BSCW Analysis Using OVERFLOW 2.2c

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OVERFLOW 2.2c

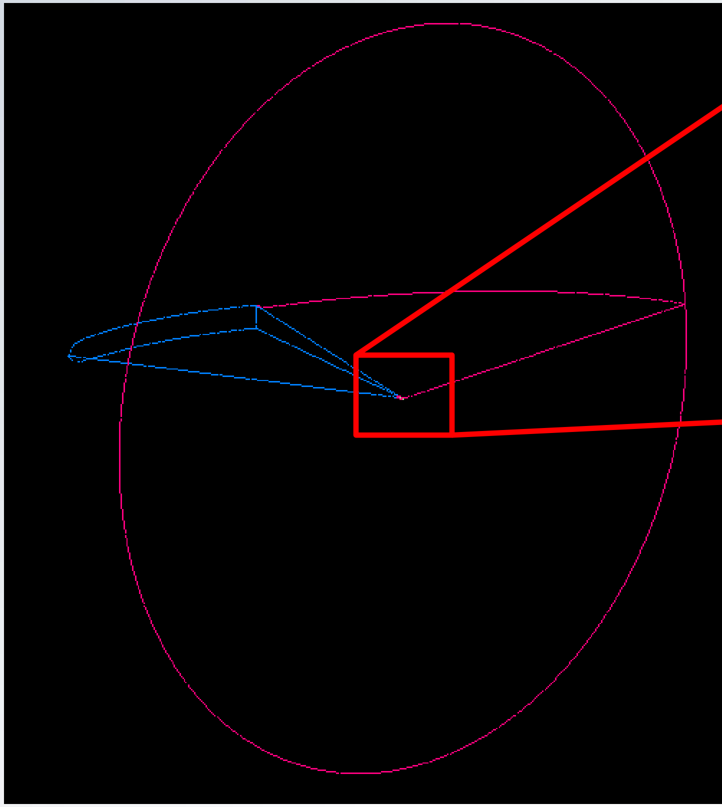
- Developed at NASA-LaRC by Dr. Pieter Buning
- Structured overset topology
- Resolves the compressible unsteady Reynolds-Averaged Navier-Stokes equations
- Wide variety of algorithm options and turbulence models
- Widely used in rotating blade systems (rotorcraft and wind energy) for aerodynamic and aeroelastic simulations

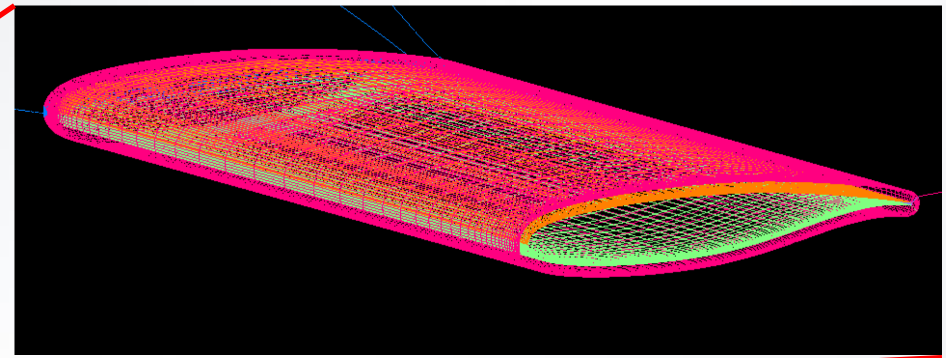
Grid Topology

- Started with structured, zonal grids developed by Pawel Chwalowski for this workshop
- Concatenated 4 body-fitted zonal grids to create one mesh around blade
- Modified existing wing end cap grid to resolve wing tip
- Required grid modifications since zonal boundary-matching mesh topologies are not permitted, only overset

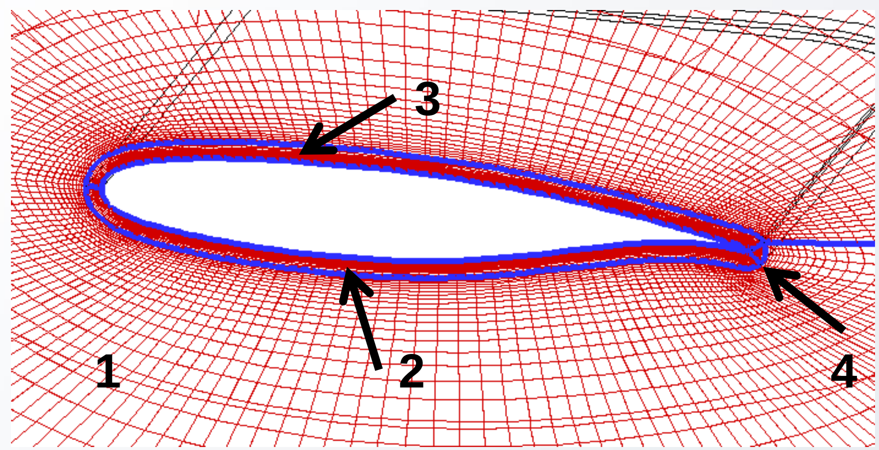
Grid	Original	Modified
Coarse	1,413,810	1,457,970
Medium	4,831,198	4,929,462
Fine	16,869,474	17,092,890

Grid Modification



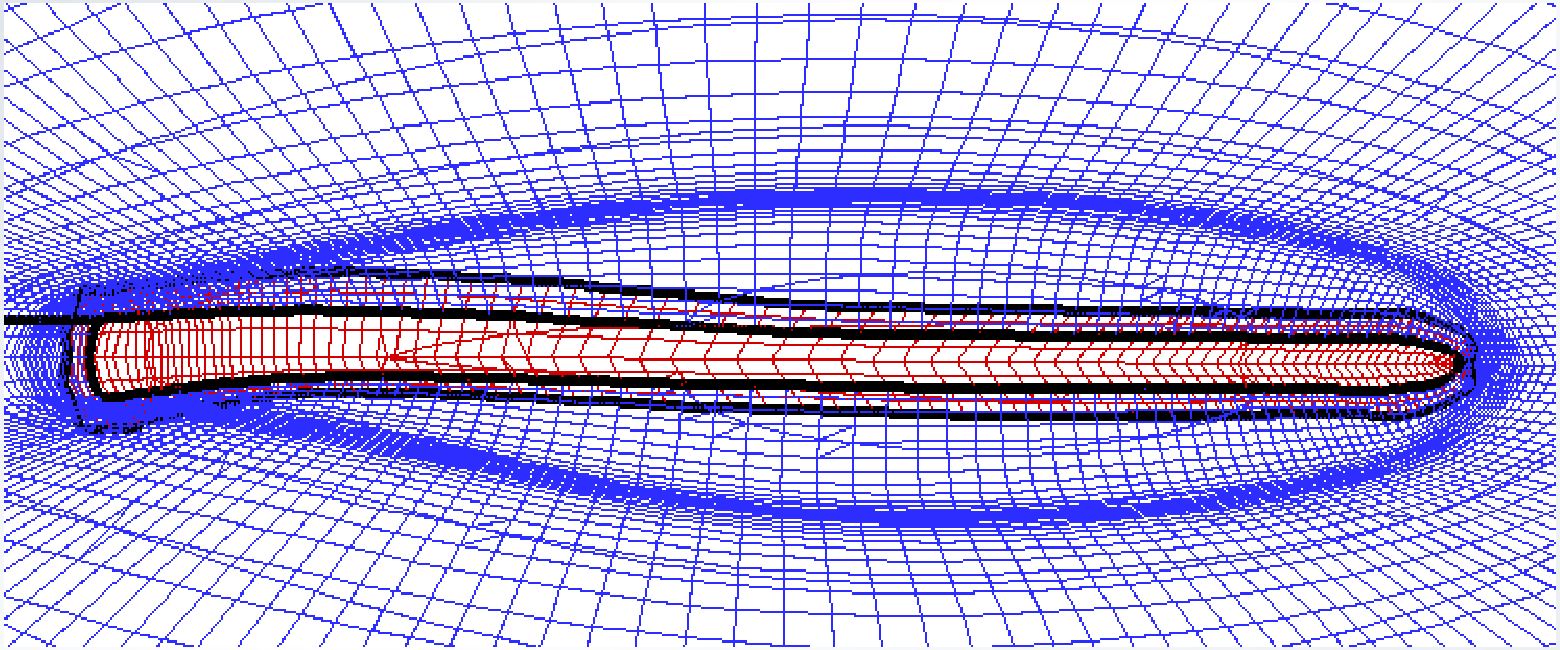


Original



Modified Grid

- Extrapolated Wing End Cap grid to create overset region with the body O-Grid.



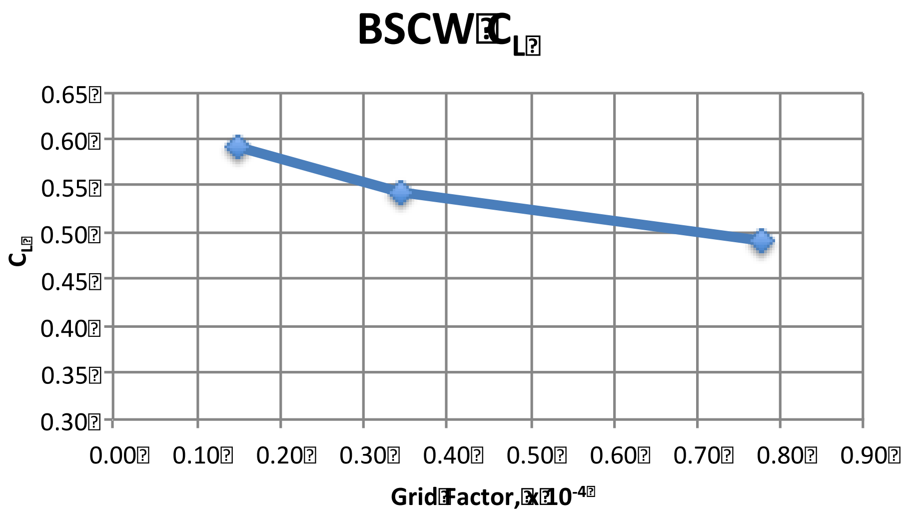
OVERFLOW 2.2c Numerical Options

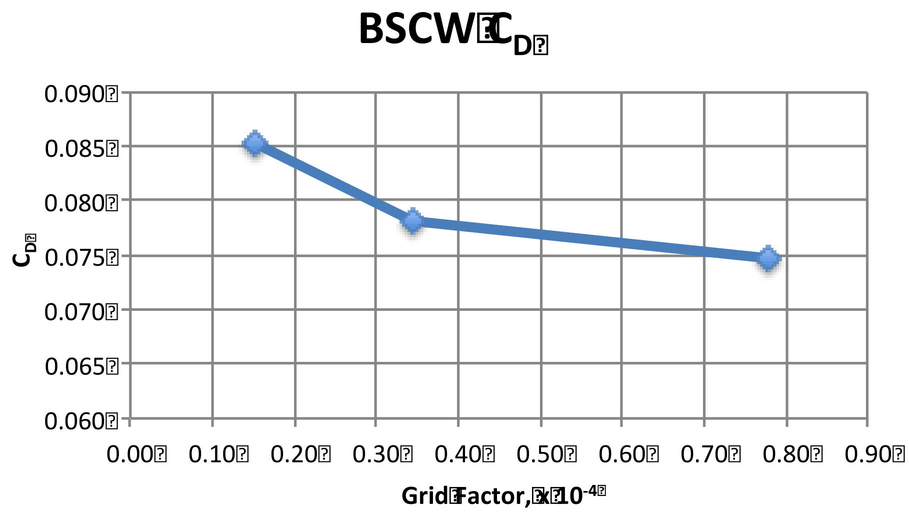
- Turbulence Model
  - Menter k-ω SST
  - SARC correction term used
- 20 Newton subiterations to achieve second-order time integration
- Numerical Methods
  - 4^{th}-order central difference inviscid terms
  - ARC3D diagonalized Beam-Warming scheme
  - TLNS3D dissipation scheme
  - 4^{th} order central difference dissipation
    - Default constants: 2^{nd} order = 2.0, 4^{th} order = 0.04
    - Changed somewhat with grid and convergence
  - 2^{nd} order differencing for turbulence convection

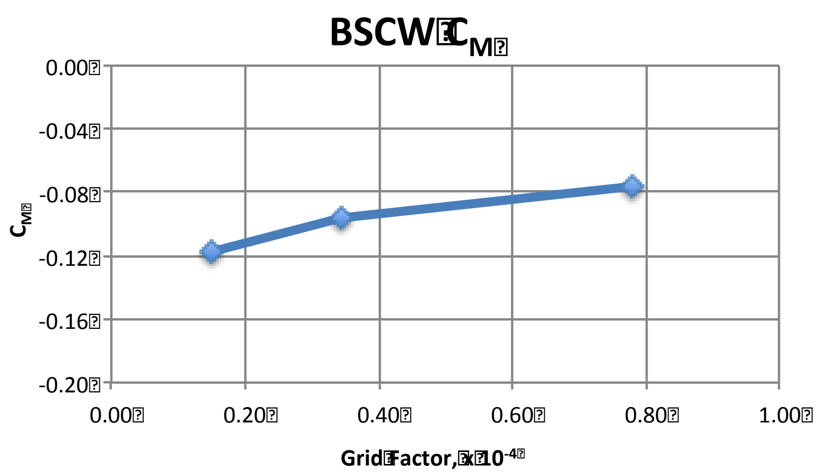
Run configuration

- Steady/Mean angle of attack, α = 5 degrees
- Free stream Mach number, M_{fs} = 0.85
- Reynolds number, Re = 4.49 Million
- Temperature, T_{fs} = 547.58 R
- Ratio of Specific Heat, γ_{fs} = 1.116
- Prandtl Number = 0.67

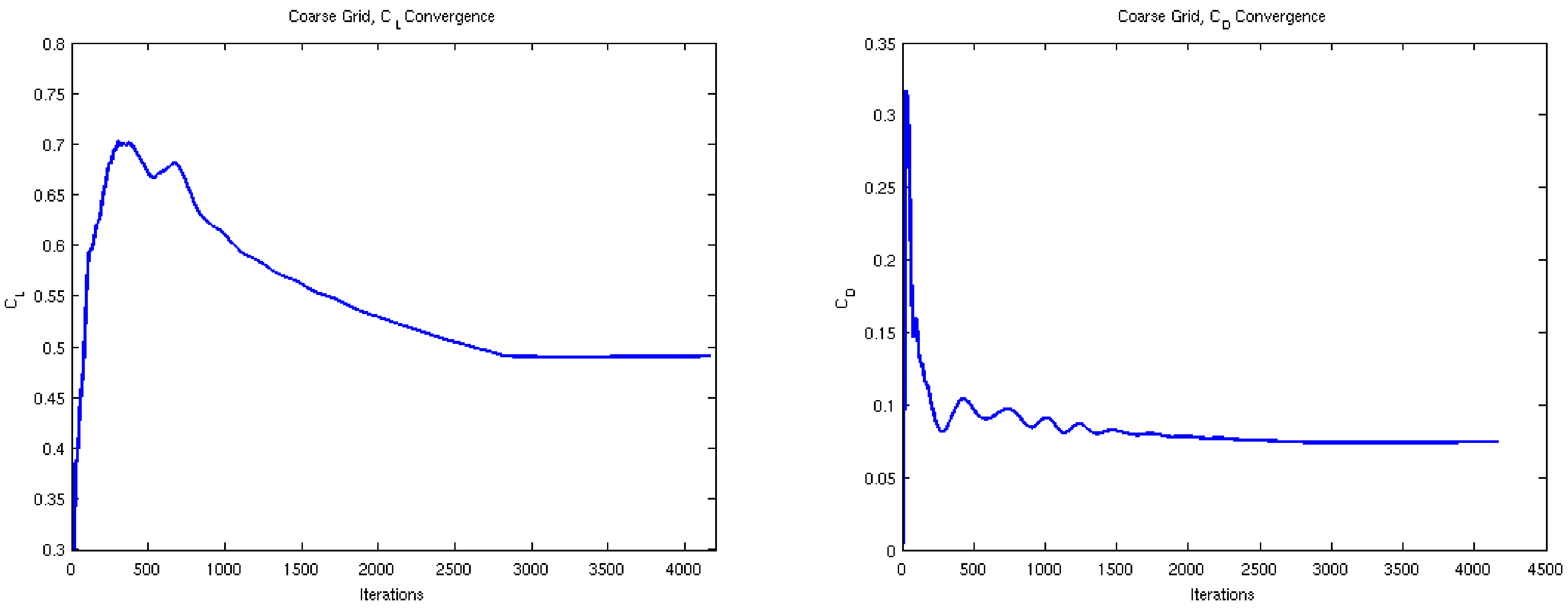
Grid Convergence



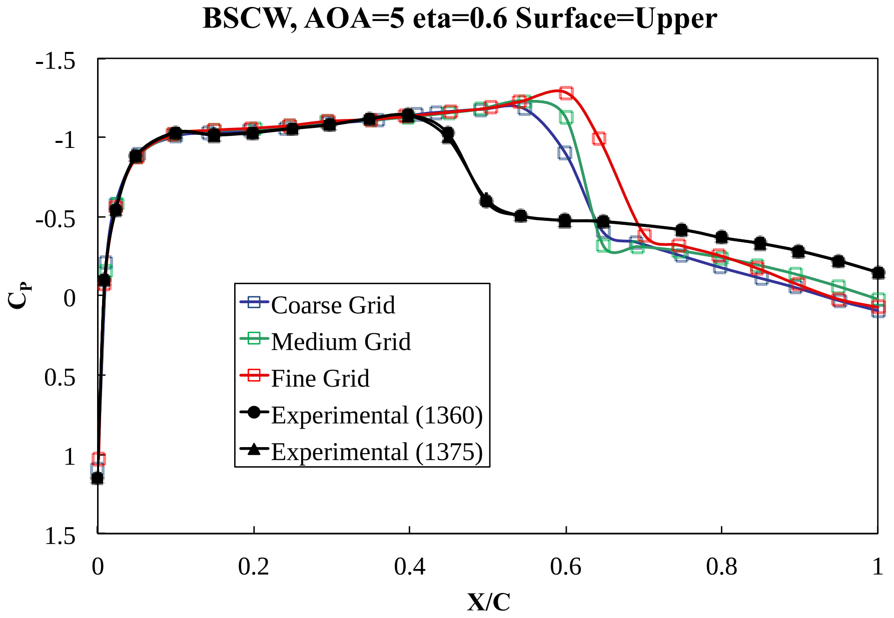


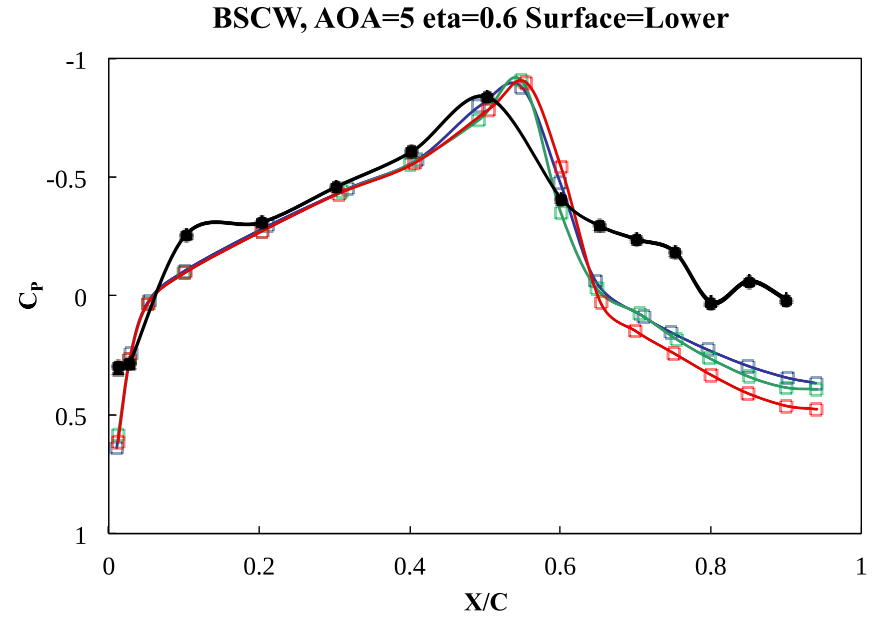


Grid Convergence (cont.)



Static Results

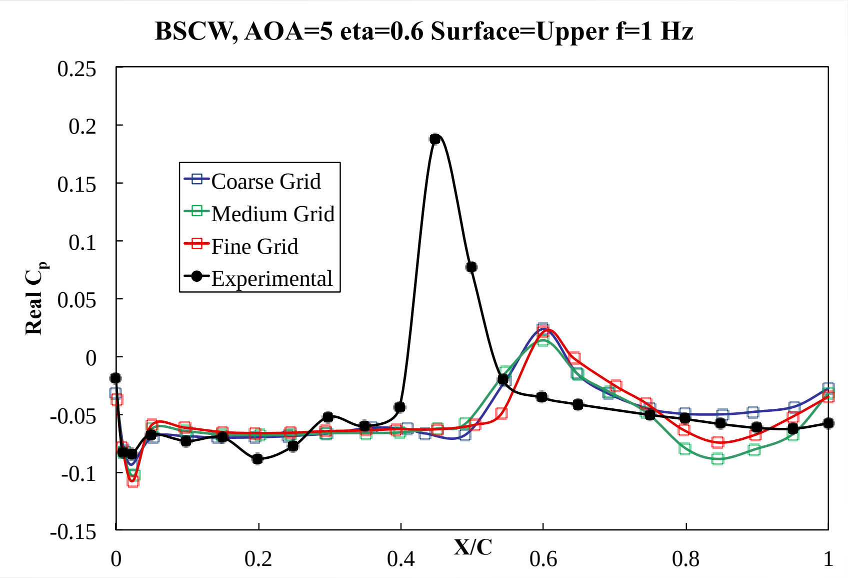


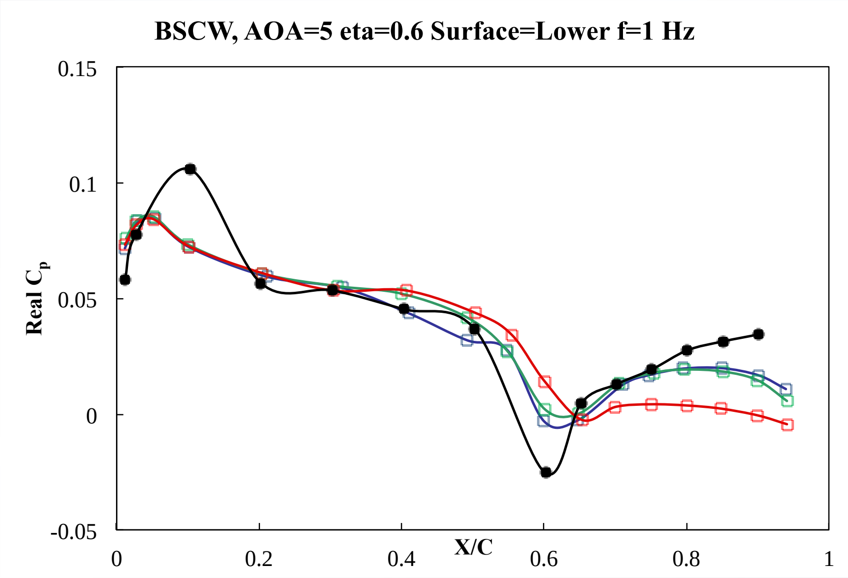


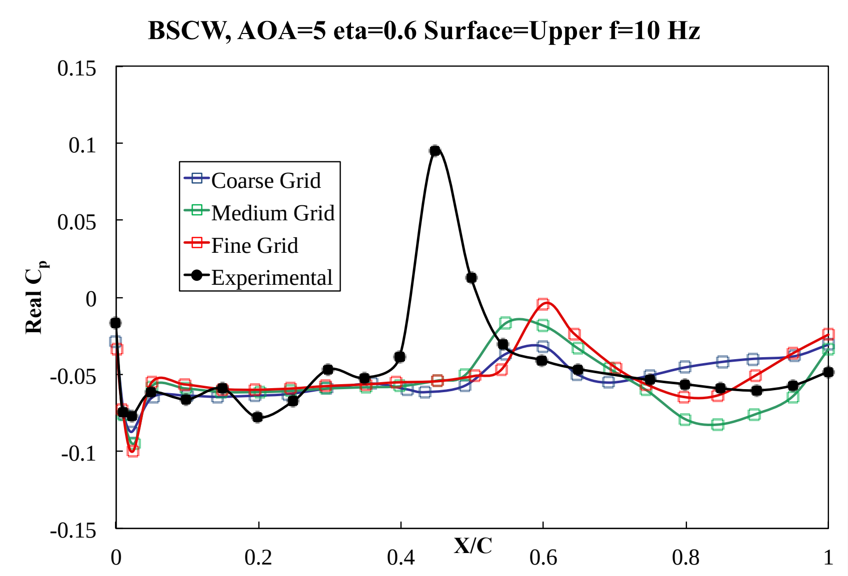
Unsteady Results

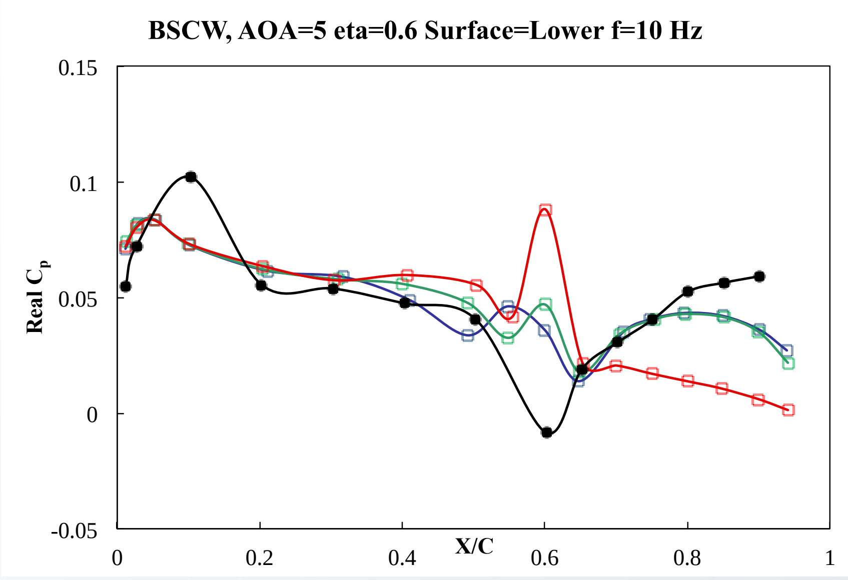
- Same general run options as steady case, but with time accuracy invoked.
- 200 physical time steps per oscillation cycle with 20 subiterations. Analysis of convergence shows these were sufficient to reach a periodic solution.
- 8 – 10 cycles were run for each grid and frequency case

Real C_p

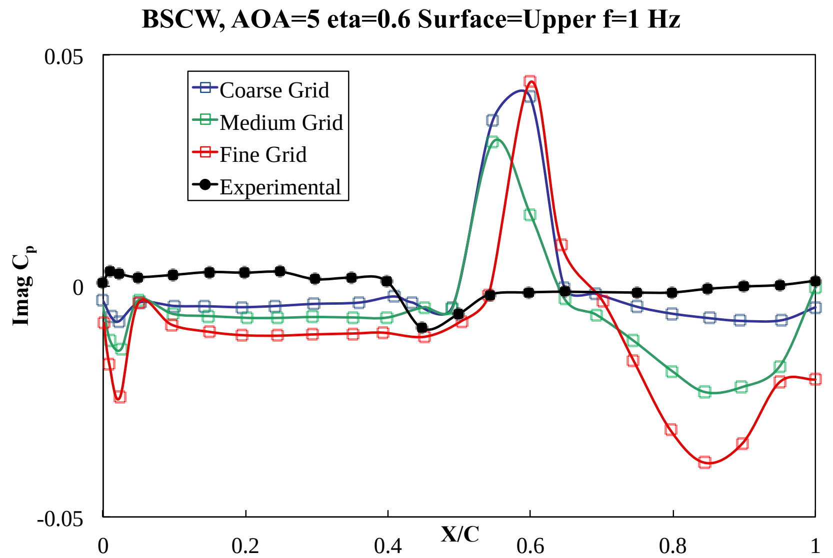

BSCW, AOA=5 eta=0.6 Surface=Upper f=1 Hz
Coarse Grid
Medium Grid
Fine Grid
Experimental
Real Cp
X/C
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
0.2
0.4
0.6
0.8
1

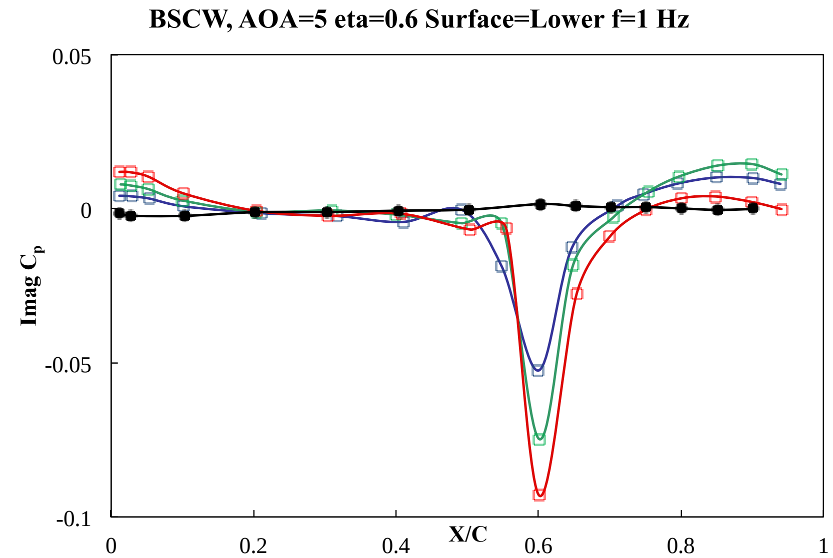

BSCW, AOA=5 eta=0.6 Surface=Lower f=1 Hz
Real Cp
X/C
0.15
0.1
0.05
0
-0.05
0
0.2
0.4
0.6
0.8
1

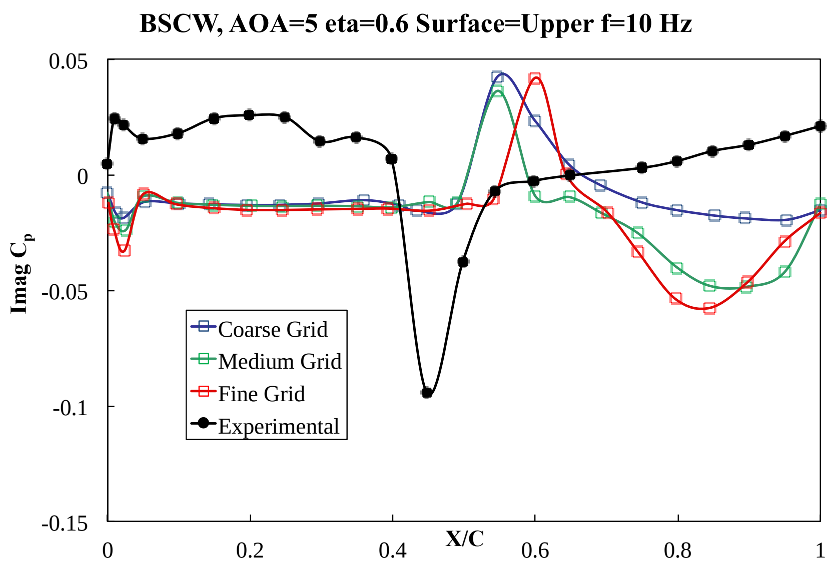

BSCW, AOA=5 eta=0.6 Surface=Upper f=10 Hz
Coarse Grid
Medium Grid
Fine Grid
Experimental
Real Cp
X/C
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
0.2
0.4
0.6
0.8
1

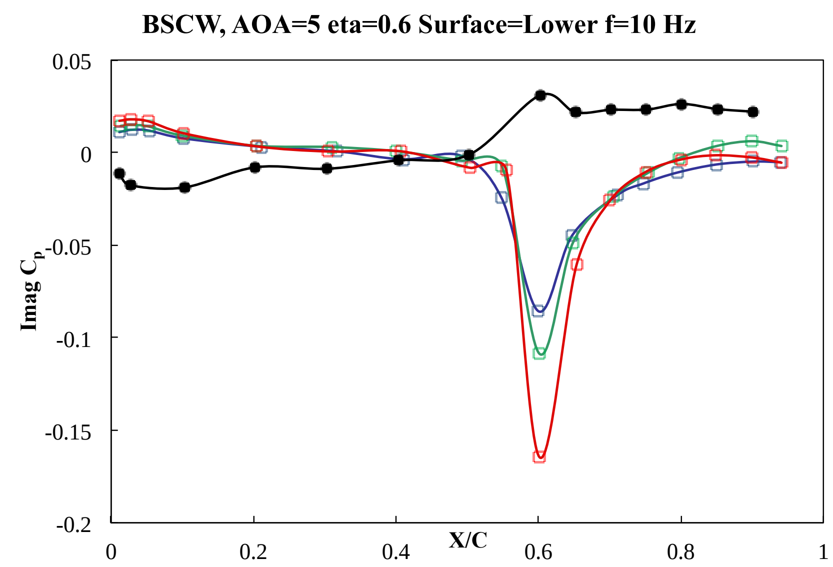

BSCW, AOA=5 eta=0.6 Surface=Lower f=10 Hz
Real Cp
X/C
0.15
0.1
0.05
0
-0.05
0
0.2
0.4
0.6
0.8
1

Imaginary C_p

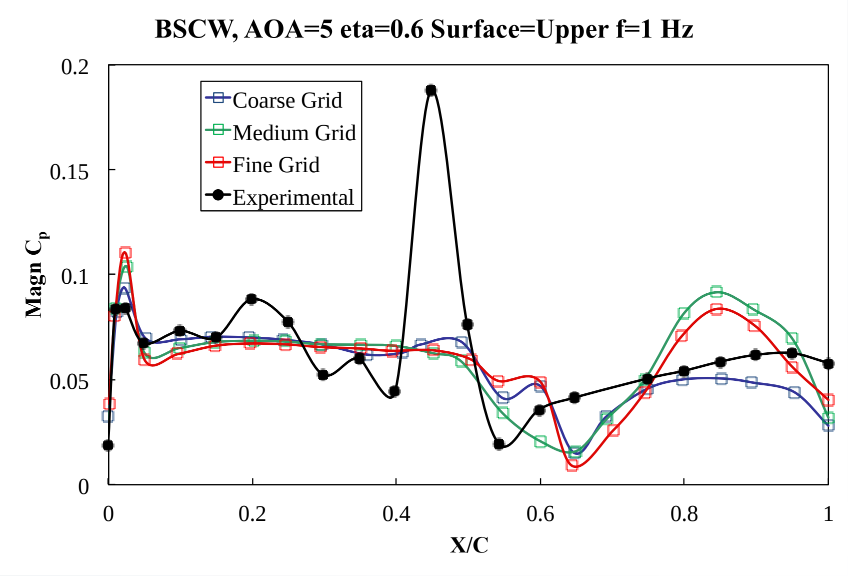


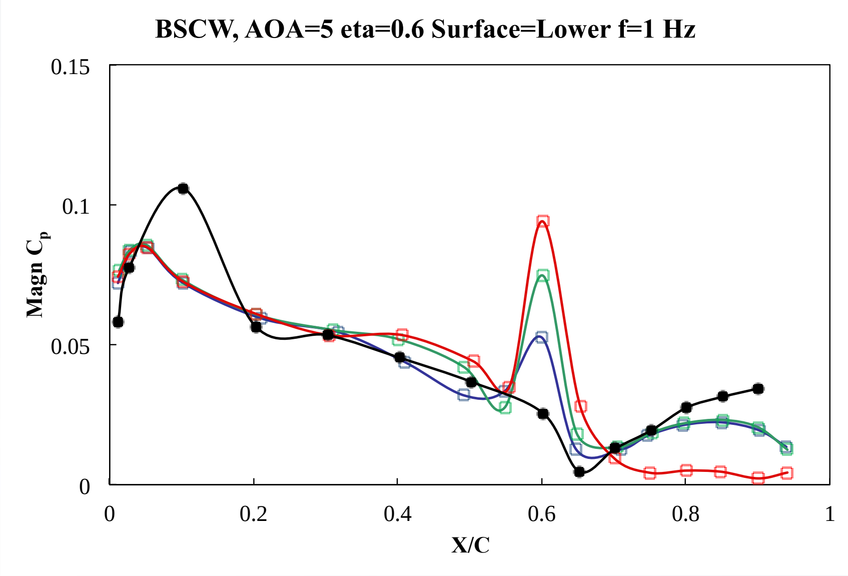


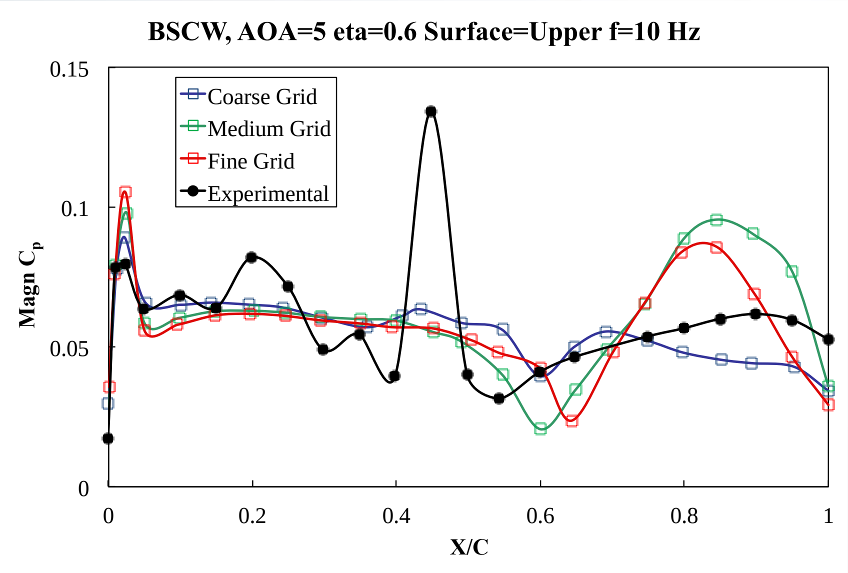


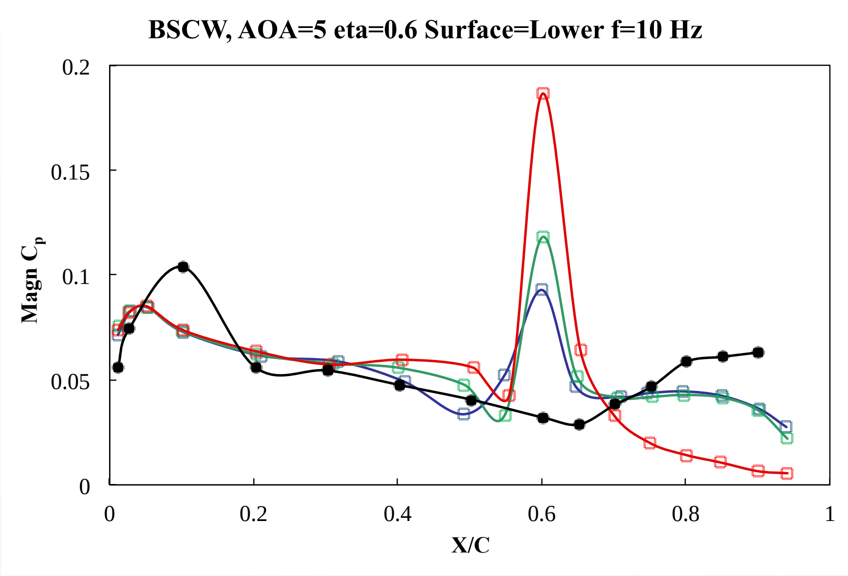


C_p Magnitude









Suggestions for future study

- Time step size and subiterations
  - For dynamic stall, we've found that periodicity in a solution does not indicate convergence to the correct physics
  - We've found that a smaller time step and more subiterations are needed to more closely capture physics of separation and reattachment – perhaps the same for unsteady transonic flows
  - Liggett and Smith, Computers & Fluids, to appear
- Blind case was run with most common options
  - Based on comparisons, which simulations submitted correlated the best?
  - Repeat these simulations using that guidance